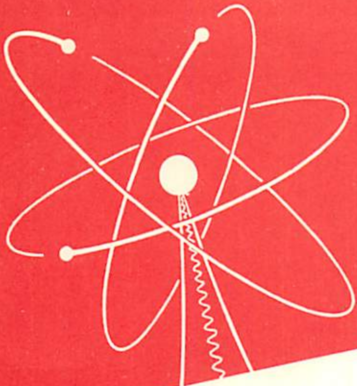

LOW VOLTAGE SUPPLIES

Lesson T2C-16A

DeVRY Technical Institute
4141 W. Belmont Ave., Chicago 41, Illinois
Formerly DeFOREST'S TRAINING, INC.

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T2C-16A

LOW VOLTAGE SUPPLIES

ELECTRONICS TELEVISION
DTI
DeVRY Technical Institute

4141 Belmont Ave.
Chicago 41, Illinois

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Tinted safety glass, a 21-inch aluminized picture tube employing 72° deflection angle, and a cascode tuner characterize this stand-mounted television receiver.
Courtesy Raytheon Mfg. Co. TV & Radio Operations

LOW VOLTAGE SUPPLIES

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Not one person in a thousand knows a good thing when he sees it, and without salesmanship and advertising we would still be a nation of bicyclists.

—William Feather

LOW VOLTAGE SUPPLIES

The circuits and tubes in a television receiver present a large number of different voltage and current requirements. However, by means of various voltage dividing arrangements, the receiver stages can be so grouped that all can be supplied from only a few output terminals of the receiver power supply. The sync circuits and most of the signal circuits require from about 30 to 300 volts, while the output signal circuits and the deflection circuits require from 200 to 600 volts. The total plate and screen currents of all these stages amounts to several hundred milliamperes. On the other hand, the picture tube anode operates at from 10,000 to 30,000 volts, but the beam current is only a few hundred microamperes.

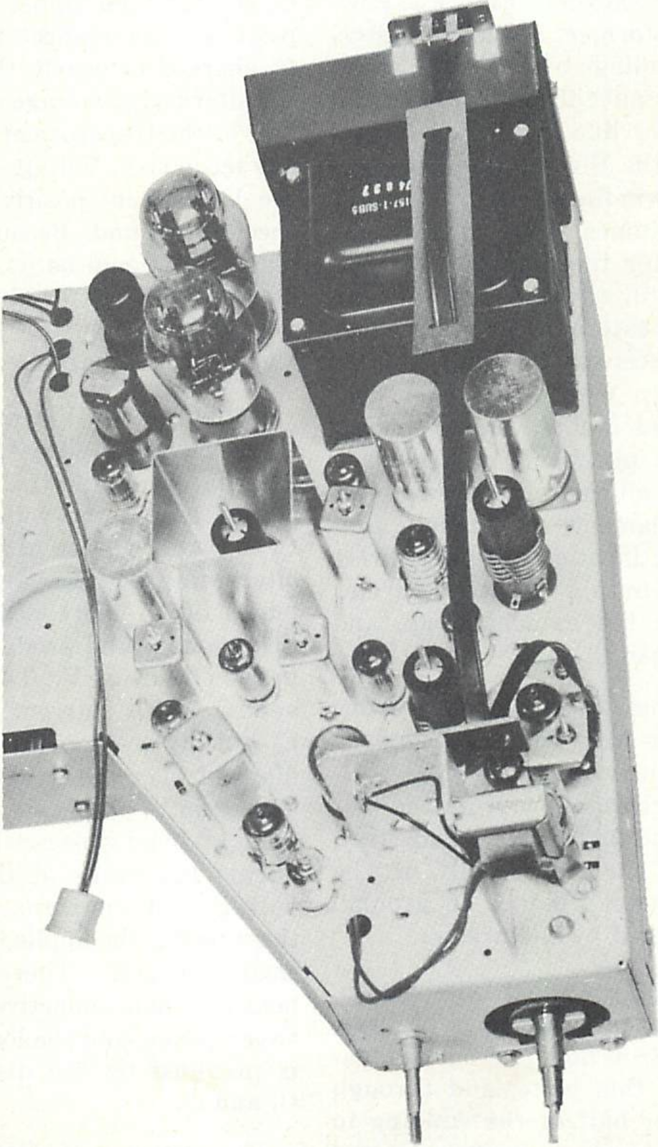
Described in another lesson, the high voltage supply provides the picture tube anode voltage and beam current requirements. Also, the horizontal deflection damper circuit produces a boost voltage of 300 to 600 volts for those tubes in which the plates are operated at voltages in this range. The large majority of tubes in the television receiver operate in the lower voltage range mentioned, and obtain their electrode potentials from the low voltage supply. In addition, the low voltage supply provides the power for the B+ boost and high voltage supplies. Thus, since all operating voltages and currents employed in the television receiver are obtained either directly or indirectly from the low voltage supply, this supply is the one single circuit which can affect the operation of any stages, group of stages, or all the stages in the receiver.

This lesson describes the low voltage supply circuit arrangements commonly employed in television receivers, and the means by which the required operating voltages and currents are distributed to the various tubes.

In most television receivers, the low voltage supply has two or more output terminals to provide the direct voltage needs of the various stages. Most of the output voltages are higher than the a-c line voltage applied to the input terminals of the supply circuit. Therefore, the low voltage supply employs some means of increasing the line voltage to the values required. Two methods of accomplishing this voltage increase are the use of a primary-to-secondary turns step up transformer, called the power transformer, and a voltage multiplying circuit, such as a doubler or tripler. Both of these methods are employed in television low voltage supplies.

POWER TRANSFORMER SUPPLIES

The basic circuit of the power transformer type of low voltage



As shown in this partial view of a television receiver chassis, the low voltage supply is an integral part of the electronic equipment it is designed for. The two rectifier tubes are visible to the left of the transformer and two of the filter capacitors are mounted directly in front of the transformer.

Courtesy "Mars" Television Inc.

supply is shown in Figure 1. Power transformer T_1 has the alternating voltage of 117 v applied to the terminals of its primary from the power line. From top to bottom, in the Figure, the three secondary windings respectively provide voltages and currents as needed for the filament of rectifier V_1, for the plates of V_1, and for the heaters of the other tubes in the receiver. The high voltage secondary winding is connected to ground and the rectifier such that the plates of V_1 are made positive alternately with respect to the filament. As a result, full-wave rectification produces direct current in V_1, the transformer winding, the external load, and filter choke L_1.

Tracing the electron paths, when the high voltage secondary makes the upper plate of V_1 positive, electrons flow from the filament to this plate, and then through the upper half of the transformer winding to ground, as indicated by the arrows.

During the next alternation, the lower plate of V_1 is positive, and electron flow is from the filament to this plate, and through the lower half of the winding to ground. Filter capacitors C_1 and C_2 and choke L_1 smooth the rectifier current pulsations to provide a constant voltage at the output terminals. As the arrows indicate, V_1 current charges C_1 and C_2 so that their upper plates are positive with respect to ground. C_1 charges to nearly the peak of the alternating voltage across one-half of the transformer high voltage secondary. Voltage E_{C_1} biases the V_1 filament positive with respect to ground. Because of this bias, there could be no more conduction of V_1 after the first applied alternation, if C_1 were not allowed to discharge.

Actually, after V_1 current stops, C_1 discharges slightly through the external load and L_1. This discharge lowers the voltage across C_1 so that the peaks of the applied alternating voltage can make the plates of V_1 more positive than the filament and produce current in the circuit of V_1, T_1 secondary and C_1. This current recharges C_1 quickly to again increase the filament bias and cutoff the tube. Thus, the V_1 plate current has the form of brief pulses which occur during the peaks of the applied voltage alternations. Between these peaks, the applied voltage is smaller than E_{C_1}. Therefore, V_1 is held in a nonconductive state between peaks, and the load current is provided by the discharge of C_1 and C_2.

The charge and discharge action of C_1 causes E_{C_1} to be a "pulsating" direct voltage; that is, a direct voltage to which an alternating component is added. Notice L_1 and C_2 form a series circuit across C_1. When C_1 is charging, the rising voltage E_{c_1} causes C_2 to charge through L_1. However, the inductance of L_1 prevents rapid changes of the C_2 charging current. As a result, E_{c_2} does not change as much as E_{c_1}. Most of the voltage change occurs across L_1. The choke L_1 and capacitor C_2 may be considered a voltage divider across C_1, such that the alternating component of E_{c_1} is across L_1 while the direct component is across C_2. On this basis, E_{c_2} is the supply output voltage applied to the load.

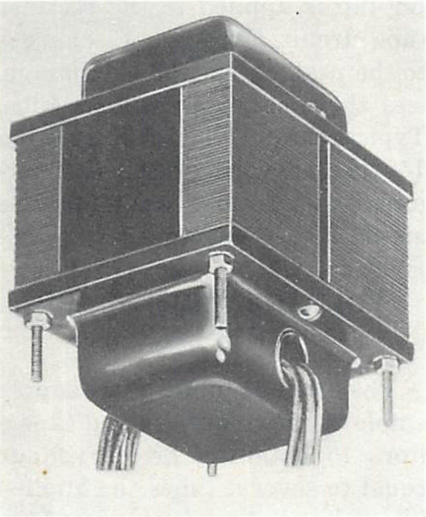
The current in L_1 produces a voltage across this coil. As a result, the voltage between the B+ and B− terminals is somewhat lower than the average level of E_{c_1}. For receiver stages which require a higher voltage than that at the B+ terminal, voltage E_{c_1} is made available by means of a second output terminal called B++. The load current in the circuits connected to this terminal consists of electron flow from the negative plate of C_1 to ground, through the load circuit to B++, and to the positive plate of C_1. Thus, both C_1 and C_2 act as reservoirs to supply power to the loads during the periods when V_1 is not conducting. In the conduction intervals, part of the V_1 current supplies the loads, while the remainder recharges C_1 and C_2. Since V_1 conduction has the form of brief pulses, most of the time the load circuits are supplied from the stored charge on the filter capacitors.

Because of the step-up turns ratio, the voltage across the high voltage secondary of T_1 is several times the voltage applied to the primary. The voltage between each end of the secondary and the center tap is applied to the rectifier tube circuit. Capacitor C_1 charges to the peak of the applied voltage, less the voltage across the tube. Typical output voltages are from 150 to 380 volts at the B+ terminal, and from 300 to 400 volts at the B++ terminal.

VOLTAGE MULTIPLIER SUPPLIES

The voltage multiplier supply employs only rectifiers and capacitors to obtain a direct voltage equal to several times the applied line voltage. An advantage of the system is that a power transformer is not needed. The simplest voltage multiplier is the doubler. However, the basic principles of operation are the same for all multiplier circuits, with minor variations. The doubler employs two rectifiers and two capacitors. Higher orders of multiplication are obtained by adding rectifiers and capacitors. Thus, a tripler contains three rectifiers and three capacitors, and so on. Two basic types of voltage doublers are employed in low voltage supplies, the full wave type and the half wave type.

Figure 2 shows a full wave voltage doubler supply. Wire A of the 117 v a-c input connects to the cathode of V_2 and to the plate of V_1. Capacitors C_1 and C_2 are connected in series between the V_1 cathode and V_2 plate, while the junction between the capacitors is connected to wire B. Connected between the V_1 cathode and the junction of the V_2 plate and lower plate of C_2, the filter consisting of choke L and capacitor C_3 removes the a-c ripple from the d-c output voltage.



A power transformer of the type used in television receivers.

Courtesy Standard Transformer Corp.

During the line voltage alternation when A is positive with respect to B, the V_1 plate is positive with respect to the cathode and the tube is conductive. As indicated by the solid line arrows, from B, electrons flow to the C_1 lower plate, and from the other plate through V_1 to wire A. This action charges C_1 to the polarity shown and to voltage E that is approximately equal to the a-c input voltage peak. During the time that A is positive, the V_2 cathode is positive with respect to its plate and the tube is nonconductive.

For the following a-c line voltage alternation, B is positive with respect to A, the V_1 cathode is positive with respect to its plate and the tube is cut off. However, at this time, the cathode of V_2 is negative with respect to the plate. As indicated by the dashed line arrows, electrons flow from A, through V_2 to the lower plate of C_2, and from the upper plate to B. This flow charges C_2 to the polarity shown, and to the voltage E, equal to that across C_1. Between peaks of the applied line voltage, the charges on C_1 and C_2 prevent conduction of V_1 and V_2. Also, these capacitors partially discharge through the circuit containing C_3 and L_1. In respect to this discharge circuit, the voltages across C_1 and C_2 are series aiding. Therefore, this discharge action charges capacitor C_3 to the value 2E. During this time, electron flow is from the negative plate of C_2 to the lower plate of C_3, from the upper plate of C_3 through L_1 to the positive plate of C_1, and from the negative plate of this capacitor to the positive plate of C_2. Thus, across C_3, the voltage 2E is the output of the voltage doubler circuit. Coil L_1 and capacitor C_3 serve the same purpose here as L_1 and C_2 in the circuit of Figure 1.

With a load connected between B+ and ground, current is drawn from the supply and the average voltage across C_1 and C_2 is somewhat less than the a-c line peak. Likewise, the average output voltage is somewhat less than twice the a-c line peak.

Since a power transformer is not used, often equipment employing this type of low voltage supply has the heaters of its other tubes connected in series across the a-c power line. However, this arrangement places the heater that is connected to the B wire of the power line at a direct voltage of E volts above ground. Since the cathode of the same tube is at or near ground potential, there is a comparatively high direct voltage between the cathode and heater, in addition to the normal alternating heater voltage. Under these conditions, any cathode heater leakage tends to introduce a hum voltage into the signal circuits of the receiver.

This high heater to cathode voltage in series filament tubes is avoided by use of the half wave type voltage doubler shown in the simplified diagram of Figure 3A. Compared to the circuit of Figure 2, the cathode of rectifier V_2 is connected directly to the plate of V_1, but only one capacitor, C_2, is in series between the V_1 plate and the V_2 cathode. Capacitor C_1 is in series between point A of the a-c line and the junction of the V_1 cathode and V_2 plate. With this arrangement, it is possible to ground power line wire B as shown.

Although the two rectifiers, V_1 and V_2, conduct on alternate halves of the a-c power line cycle, the functions of the two capacitors C_1 and C_2 are somewhat different. In Figure 2, each capacitor is charged through a rectifier tube to approximately the peak line voltage and each forms a part of the output or filter circuit. In Figure 3A, only C_2 is part of the output or filter circuit, and is charged to approximately twice the peak line voltage. Capacitor C_1, charged to approximately the peak line voltage, acts as a reservoir which adds its energy to that of the power line during the interval that C_2 is being charged.

To follow the action, first refer to Figure 3B and assume an a-c power line alternation during which wire B is positive with respect to wire A. With this polarity, the plate of V_1 is positive with respect to the cathode, the tube is conductive and capacitor C_1 is charged to the indicated polarity. For this interval, the plate of V_2 is negative with respect to the cathode, the tube is nonconductive, and the only active part of the input circuit is that shown by the solid lines in the Figure.

Every circuit in the television receiver depends upon proper operation of the low voltage supply.

Courtesy Bendix Radio
Division of Bendix Aviation Corp.

Following the arrows, electrons move from negative wire A into capacitor C_1, causing its lower plate to become negative. This surplus on the negative plate causes electrons to leave the other plate and move to the cathode of V_1 through the tube to the plate and back to positive line wire B. Thus, the V_1C_1 charging circuit of Figure 3B is similar to the V_2C_2 charging circuit of Figure 2.

Referring again to Figure 3A, during the following a-c power line alternation, wire A is positive with respect to wire B, therefore the plate of V_1 is negative with respect to its cathode and the tube is nonconductive. During this interval, V_1 is equivalent to an open circuit and the active portion of the circuit is shown by the solid lines in Figure 3C. With wire A positive and wire B negative, the line voltage is in series with the charge on capacitor C_1, and therefore, the total of these two voltages, equal approximately to twice the line voltage, is applied to the series circuit consisting of V_2 and C_2.

With this polarity of applied voltage, the plate of V_2 is positive with respect to its cathode, therefore the tube is conductive and charges C_2 to the indicated polarity. As shown by the arrows, electrons move from wire B to the negative plate of C_2, from the positive plate of C_2 to the cathode of V_2, through the tube to the plate, to the positive plate of C_1, and from the negative plate of C_1 to wire A. As the total voltage applied to the V_2C_2 circuit is that of two series sources each equal to the peak line voltage, capacitor C_2 is charged to approximately twice the peak line voltage.

Referring again to Figure 3A, C_2 is the input capacitor of the filter which includes choke L_1 and output capacitor C_3. C_2 discharges to supply the current for the load circuits connected across the filter output between B+ and ground.

In actual operation this discharge into the load is continuous, except during the brief intervals of V_2 conduction. Therefore, the average direct voltage across C_2 is somewhat less than twice the peak line voltage. Also, since some energy from C_1 charges C_2 during a part of the input power cycle, the average voltage across C_1 is somewhat less than the peak supply line voltage.

The arrows in Figures 3B and 3C indicate a reversal of electron flow in C_1 and make it appear that a non-polarized type of capacitor is required at this point. However, when in operation, C_1 is charged during the alternation illustrated in Figure 3B and discharges but partially during the following alternation illustrated in Figure 3C. This complete action is repeated during each input cycle and, as the charge equals the partial discharge, the polarity remains as indicated at all times. Therefore, the polarized electrolytic type of capacitor is used.

When it is desirable to obtain voltage outputs greater than twice the input line voltage, the system of Figure 3A may be extended as shown in the circuit of Figure 4. Any number of rectifier tubes and capacitors may be used. However, with the heaters of the rectifiers connected across the a-c power line, in practice the number is limited by the dangerously high potential differences that are developed between the heaters and the cathodes of the tubes at the high voltage end of the system. Transformers could be provided to correct this condition but they would require separate well insulated filament windings for each tube and the simplicity of the system would be lost.

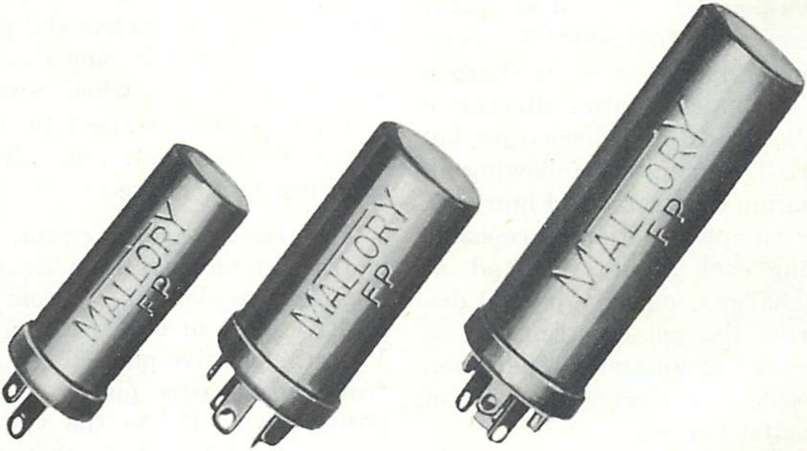
In operation, the action of the circuit of Figure 4 is similar to that explained for Figure 3A. When wire A of Figure 4 is positive with respect to wire B, tube V_1 conducts and charges capacitor C_1 to approximately the peak line voltage "E." During the following alternation when wire A is negative with respect to wire B, tube V_2 is conductive and allows capacitor C_2 to charge.

The active charging circuit can be traced from negative wire A to the negative plate of C_2, from the positive plate of C_2 through tube V_2 to the positive plate of C_1, and from the negative plate of C_1 to positive wire B. As the voltage across line A-B and the charge of capacitor C_1 are series-aiding, capacitor C_2 is charged to voltage 2E, approximately twice the line voltage.

During the next alternation, wire A is positive again, tube V_3 is conductive and allows capacitor C_3 to charge. At this time, line voltage E and the 2E charge of capacitor C_2 are series-aiding so that capacitor C_3 is charged to approximately three times the line voltage, indicated as 3E. In addition, capacitor C_1 is charged, as explained above, to replace the energy it released to help charge C_2.

Following the same plan, when wire B is positive again, tube V_4 is conductive and allows capacitor C_4 to charge. In this charging circuit line voltage E and the 3E charge of capacitor C_3 are series-aiding so that capacitor C_4 is charged to approximately four times the line voltage, indicated as 4E. Also, at this time, capacitor C_2 is recharged to voltage 2E as explained previously.

Without repeating all the details, when wire A is positive again, tube V_5 is conductive and the line voltage E in series with the 4E charge of capacitor C_4 charges capacitor C_5 to approximately five times the line voltage, indicated as 5E. Capacitor C_N and tube V_N represent any number of such units as may be included in an arrangement of this kind and the direct voltage developed across the last capacitor C_N becomes the output of the supply.



Compact electrolytic filter capacitors mounted in aluminum cans. This type capacitor is used extensively in TV low voltage supplies.

Courtesy P. R. Mallory and Co.

At first glance it may appear that when conductive, the various rectifier tubes "short circuit" the charging action of the circuit. However, this does not occur because once the series of capacitors is charged, the individual rectifiers carry current only for that portion of the a-c cycle necessary to restore the loss of charge required to supply the load current. As soon as stable operating conditions are reached, capacitor C_1 remains charged almost to peak line voltage, capacitor C_2 remains charged almost to twice peak line voltage and so on.

HEATER CIRCUITS

In addition to the relatively high direct voltages required for the plates and screens of the various tubes in the television receiver, alternating voltage is employed to produce the needed heater currents. For most tubes, the heater operates at a much lower voltage than the a-c line voltage. The necessary low heater voltages are obtained by transformer step-down action, or by connecting the tubes in series across the line so that the heater resistances form a voltage divider.

As mentioned for Figure 1, power transformer T_1 contains a secondary winding which provides voltage and current for the heaters of the receiver tubes. Figure 5 shows the connection of heater winding L_4 to the parallel heaters of the tubes, designated V_2, V_3, V_4, etc. As all heaters are in parallel in this arrangement, they all operate at the same voltage, 6.3 volts rms. To provide this voltage across secondary winding L_4, T_1 has a turns step down ratio of approximately 18.5 to 1, from L_1 to L_4. Secondary L_4 is wound with wire heavy enough to carry the total of all the heater currents. Individual heater currents differ from each other.

The series heater system is illustrated in Figure 6. In this case, the heaters may operate at different voltages, as indicated by their type numbers, but all carry the same current. Between each two heaters, a value indicates the voltage between that point and ground. Thus, the voltage across a given heater is found by subtracting the smaller value from the larger at its terminals. For example, across the 5AT8 heater, there are approximately $57-52$ or 5 volts. Since the heater voltages total only 98 volts, resistor R_1 is added in series. The 19 volts produced across R_1 added to the total heater circuit voltage equals the applied voltage of 117 volts.

TYPICAL TV LOW VOLTAGE SUPPLIES

Transformer Types

A typical transformer type television receiver low voltage supply is shown in Figure 7. The high voltage secondary winding has a total of five taps, one of which is used to connect its center point to ground, and the others connect to full wave rectifier tubes V_1 and V_2 to provide two independent supply circuits. The plates of tube V_2 connect to the outer ends of the winding while the filament, obtaining its current from a low voltage secondary, is connected to the output filter consisting of L_1, C_1, and C_2. The negative plates of the filter capacitors, are connected directly to ground and +380 volts are available as the output at the positive plate of capacitor C_2. From the positive plate of input capacitor C_1, +400 volts are made available by a separate connection.

For this part of the supply, the complete conductive path may be traced from the filament of V_2 to either plate, to the corresponding half of the high voltage secondary winding, to its center tap and to ground. From ground, there are paths through the plate circuits of the various tubes to the +380 volt terminal, and through the filter choke L_1 to the filament of V_2. Other paths are from ground through plate circuits to the +400 v terminal, and to the filament of V_2.

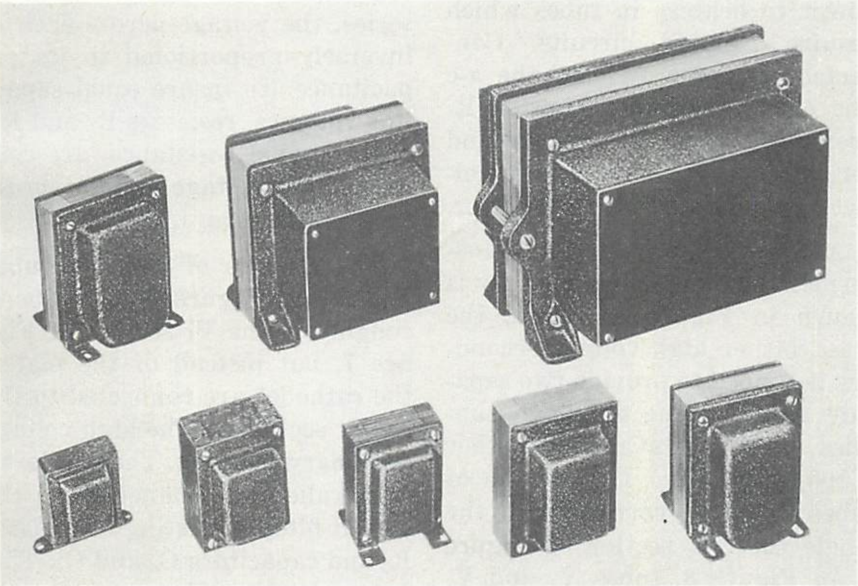
The plates of rectifier tube V_1 are connected to the remaining taps on the high voltage secondary winding. Obtaining current from another low voltage secondary, the V_1 filament is connected to the filter consisting of L_2, C_3, and C_4. Since there are fewer turns between the taps of the high voltage secondary to which the plates of V_1 are connected, the direct voltage output of this part of the supply is only +290 volts as shown.

In this section, the direct current path is from the filament of tube V_1 to either plate through the corresponding section of the high voltage secondary to the center tap, and to ground. From ground, the path continues through the tube circuits back to the +290 volt terminal and through filter choke L_2 to the filament of the tube. The current paths are traced through the rectifiers, transformer secondary, and load circuits only, for the sake of simplicity. Actually, the complete action explained for Figure 1 occurs in every case. That is, the rectifiers conduct in short pulses to charge the filter capacitors which, in turn, supply continuous current to the load.

The rectified currents of both the V_1 and V_2 sections of the supply are carried by the center sections of the high voltage secondary winding, while only the current of the V_2 section is carried by the outer sections of this winding. Therefore, between the points at which the V_1 plates are connected, the wire of the winding must be sufficiently large to carry the total current of both sections.

The filaments of rectifiers V_1 and V_2 are connected to separate filament windings while the circuits of most of the remaining tube heaters are shown near the bottom of the diagram. Each of the seventeen heaters in this group operates at 6.3 volts. By connecting them in parallel-series across a 12.6 volt center-tapped winding as shown, the total heater current which the transformer winding must supply is reduced by approximately one half. For example, if each heater requires .3 ampere, all seventeen need $17 \times .3 = 5.1$ amperes at 6.3 volts. Series connected in pairs across the entire secondary, 16 of the tubes require but $8 \times .3 = 2.4$ amperes at 12.6 volts. The center tap connection carries only the current for the 17th heater plus any unbalance between the parallel groups.

To prevent 60 cycle power line modulation of the oscillator circuit output, its heater is supplied with direct current in this particular receiver. As shown at the lower center of Figure 7, two



Power transformers are made in various shapes and sizes to meet the need of every type of electronic equipment.

Courtesy B. F. Miller Co.

selenium rectifiers, D_1 and D_2 are connected across the 12.6 volt transformer secondary to operate as a full wave rectifier. The circuit is completed from the junction between the rectifiers through resistor R_2 which, in conjunction with capacitor C_5 acts as a low pass filter. Together with capacitors C_5 and C_6, choke L_3 acts as a high frequency filter to prevent the oscillator output from feeding back into the other circuits. The two secondaries, shown at the upper left of the diagram, supply power to heaters in tubes which require isolated circuits. Connected from one side of the a-c line cord to ground, resistor R_1 provides a path to earth ground for static charges that may collect on the chassis of the receiver.

Another example of a transformer type low voltage supply is shown in Figure 8. Again, the transformer high voltage secondary is tapped to provide two separate sections, one of which supplies +400 volts and the other −100 volts. Here, the circuits of tubes V_1 and V_2 correspond to the single tube V_2 section of Figure 7. In Figure 8, tubes V_1 and V_2 are connected with their respective sections in parallel to provide twice the current handling capability of one tube. The center tap of the high voltage winding is connected to ground, and the filaments of V_1 and V_2 are connected through the contacts of relay M to the output filter consisting of C_1, C_2, and choke L_1.

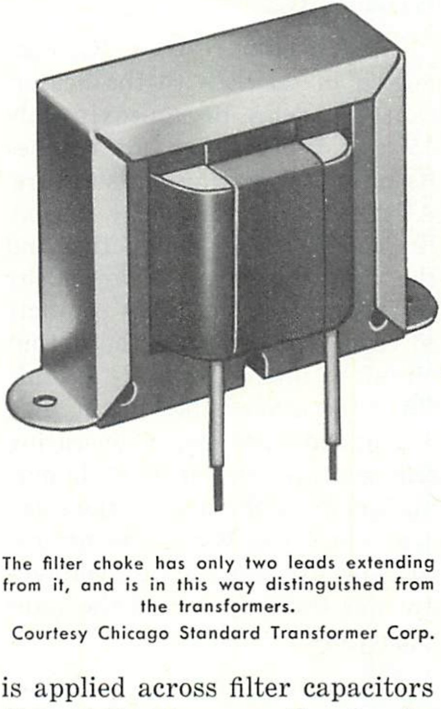
The common types of filter capacitors have a maximum rating of 450 working volts and, with 400 volts between the output terminal of choke L_1 and ground, the safety factor is small. To provide protection in this respect, filter capacitors C_1 and C_2, each rated at 350 volts, are connected in series to provide the equivalent of a 700 volt capacitor, with half the capacitance of either one. When two capacitors are connected in series, the voltage across each is inversely proportional to its capacitance. To insure equal capacitor voltages, resistors R_1 and R_2, having equal resistance, are connected as a voltage divider across these capacitors.

The circuits of rectifier tubes V_3 and V_4 Figure 8, correspond roughly to the V_1 section of Figure 7, but instead of the plates, the cathodes are connected to the center sections of the high voltage secondary winding. The plates, all in parallel, are connected to the output filter consisting of resistor R_3 and capacitors C_3 and C_4. This reversal of rectifier tube connections makes the ground side of this section positive and the output terminal 100 volts negative.

In this section of the supply, the rectifier tubes are conductive only during the secondary voltage alternations that the cathode is negative with respect to ground. Thus, as in most full wave rectifiers, tubes V_3 and V_4 are alternately conductive. During conduction, electrons travel from the cathode to the plates of either tube, through filter resistor R_3 to the "−100v" output terminal. From that point, the path is through a load circuit to ground, to the center tap of the secondary, and through either central section of the winding to the cathode of the conductive tube.

Other circuits are connected across the −100 v and +400 v terminals for a total supply of 500 volts. For these, the return path of the electrons is through choke coil L_1, the contacts of relay M, filament to positive plate of tubes V_1 and V_2 to the outer end of the secondary, and through the winding to the negative cathode of V_3 or V_4.

The time delay circuit, consisting of tube V_5, relay M, and resistor R_4 of Figure 8, prevents high surge voltages across filter capacitors C_1 and C_2 in the 400 v supply circuit when the power is first turned on and the various tubes are not warmed up sufficiently to draw their normal load currents. When the circuits supplied are not in operation, there is no current in the winding of relay M, and its contacts are open to disconnect the filaments of tubes V_1 and V_2 from the output filter components. When transformer primary circuit switch SW is closed, the induced secondary voltages of the power transformer are applied to all the rectifier tubes. Since the contacts of relay M are open, the V_1 and V_2 output circuit is broken and no voltage is applied across filter capacitors C_1 and C_2. However, the circuits of rectifiers V_3 and V_4 are complete, therefore filter capacitors C_3 and C_4 are charged to approximately 100 volts at the indicated polarity.



The filter choke has only two leads extending from it, and is in this way distinguished from the transformers.

Courtesy Chicago Standard Transformer Corp.

Triode V_5 is converted to a diode by connecting the control grid to the plate, which in turn, is connected through the winding of relay M to the grounded positive plates of filter capacitors C_3 and C_4. The cathode of V_5 connects directly to the negative plate of C_4 and through filter resistor R_3 to the negative plate of C_3. Thus, the voltage of the charged capacitors is applied across diode V_5 in the proper polarity to make it conductive.

The 10 ohm resistor R_4, connected in series with the heater, causes a delay of approximately 15 seconds before the tube reaches its proper operating temperature. At the end of this delay period, the tube becomes conductive and the resulting current, carried by coil M, causes the relay contacts to close and complete the output circuit of tubes V_1 and V_2. By this time, the other tubes in the load circuits are at proper operating temperature, and draw their normal currents the instant the relay contacts close. With this normal current, excessively high voltages are not built up across the filter capacitors C_1 and C_2.

Although not related to the action of the voltage supply of Figure 8, capacitors C_5 and C_6, connected across the primary of T_1, form a line "noise" filter.

A third arrangement of the power transformer type of low voltage supply is shown in Figure 9. It includes separate power transformers T_1, T_2, and T_3, and four rectifier tubes V_1, V_2, V_3, and V_4. This supply is employed in a projection type television receiver.

Tube V_1 operates as a full wave rectifier across the center tapped high voltage winding of power transformer T_1 and provides voltages for the receiver audio amplifier circuits only. The filament is connected to the filter consisting of capacitor C_1, choke L_1, and capacitor C_2 with the series bleeder resistors R_1, R_2, and R_3 across its output. Resistor R_3 is connected between ground and the center tap of the high voltage winding to provide a negative 25 volts to bias the control grids of the audio output tubes. The plate circuits of the audio output tubes are connected to the +380 volt terminal which connects to the positive plate of the input filter capacitor C_1 and through jumper "J" to filter choke L_1. This jumper is located in the speaker plug so that the high voltage cannot be applied to the plates of the output tubes unless the speaker is connected.

To provide for the relatively high voltage and current requirements of the horizontal deflection circuits, full wave rectifier tubes V_2 and V_3 are connected in parallel across the high voltage secondary winding of power transformer T_2. The filaments of these tubes are connected to the filter consisting of capacitors C_3 and C_4, choke L_2, and capacitors C_5 and C_6. As explained for C_1C_2 and R_1R_2 of Figure 8, there are voltage divider resistors across the series connected capacitors. An output of +475 volts is available at the common junction of L_2, C_5 and R_6.

As is common, the receiver has its high voltage supply energized by the horizontal sweep circuit. Therefore, to provide protection against high voltage shock, a safety or interlock switch is included in the 117 volt supply circuit. Referring to the lower part of Figure 9, "S_1" is the normal off-on power switch which, when closed, energizes the primary of transformer T_1. With S_1 closed, the primaries of transformers T_2 and T_3 are energized only when plug P_1 is inserted in its socket. In addition, plug P_2, connected in series with the primary of transformer T_2, is located on the safety cover of the high voltage supply.

Thus, when the safety cover is removed, plug P_2 is separated from its socket and this entire section of the power supply becomes inoperative. In a similar manner, if this section of the supply is removed, plug P_1 must be pulled out of its socket and again the circuits are inoperative.

The remaining positive and negative voltage requirements of the receiver are provided by the power supply consisting of full wave rectifier tube V_4, power transformer T_3, and filter $C_7L_3C_8$. Beginning at the +150 volt output terminal of this supply, the voltage divider consists of series connected resistors R_8, R_9, R_{13}, R_{12}, R_{11}, and R_{10}. The total output is 260 volts but, with the grounded

A full wave rectifier tube, the 5AW4 is employed in low voltage power supplies.
Courtesy CBS

junction between R_9 and R_{13} as a reference, the polarities and values of the available voltage are as indicated.

Also, as shown in Figure 9, each transformer has low voltage secondaries to supply current for the filaments of its rectifier and the heaters of certain tubes in the receiver circuits.

Voltage Doubler Types

Although diode tubes are shown in the circuits of Figures 2, 3, and 4 to illustrate voltage multiplier action, television receiver low voltage supplies which employ voltage doubling usually contain selenium rectifiers. An example is the circuit of Figure 10. Here, the two selenium rectifiers, D_1 and D_2, are arranged with capacitors C_1 and C_2 to form a half wave voltage doubler. When switch S_1 is closed, the 117 volts of the a-c power line are applied through resistor R_1 to C_1 and D_1 in series.

During the alternation that line terminal A is negative, electrons flow from this terminal through R_1 into C_1, and from C_1 to the cathode (rectangle) of rectifier D_1. The path continues through the rectifier from cathode to anode (triangle), to ground, and through S_1 to the B terminal of the line. This flow charges C_1 to approximately the line voltage peak, and to the indicated polarity. During the alternation that line terminal B is negative, the voltage across C_1 and the line voltage act in series to charge C_2 through D_2. Electrons flow from terminal B, through S_1 to ground, into the lower plate of C_2, from C_2 through D_2 to C_1, and from C_1 through R_1 to terminal A. This action charges C_2 to approximately twice the peak line voltage, with no load.

The voltage across C_2 is the output of the doubler circuit, and is applied to the filter network consisting of L_1, C_3, C_4, R_3, and C_5. Connected to various points in this network as shown, output terminals make available direct voltages of +255, +250, and +150 volts, respectively. As explained, load current discharges C_2 somewhat so that its voltage is considerably less than twice the line voltage peak.

Low value resistor R_1 serves as a fuse to protect the voltage supply components in the event of a short in a load circuit. The a-c line voltage is applied through R_2 to the heaters of the receiver tubes which are connected in series as in Figure 6.

The low voltage supply of Figure 11 is an example of the full wave type voltage doubler. The a-c line connects to the circuit through an "interlock" plug. With this arrangement, the male plug is mounted in the rear of the receiver chassis, and the female plug in the masonite cover that fits on the back of the cabinet. The plugs are engaged to apply line voltage to the supply only when the cover is fastened to the cabinet. This is a safety feature employed to protect the receiver owner from electric shock, since removing the back cover also removes power from the receiver.

In the circuit of Figure 11, when the power switch S_1 is closed, the a-c line applies 117 volts through "fuse resistor R_1" to the junction between selenium rectifiers D_1 and D_2, and to the junction between capacitors C_1 and C_2. When the lower side of the line is negative, electrons flow from this side into C_1, and from C_1 through D_1, R_1, and S_1 to the upper side of the line, charging C_1 as indicated. During the next alternation, electrons flow from the upper side of the line, through S_1, R_1, and D_2 into C_2, and from C_2 to the lower side of the line. This flow charges C_2 as indicated. In series, the voltages across C_1 and C_2 constitute the "doubled" output. Filter choke L_1 and the capacitance voltage divider C_3C_4 provide direct output voltages of +260 and +150 volts with respect to ground.

This receiver employs tubes with parallel heaters. The filament transformer T_1, connected across the line, steps down the line voltage to the 6.3 volts required by the heaters. Fuse F_1 protects the transformer in the event of a short in the heater circuit.

Some tube heaters are in parallel while other heaters are in series in the receiver model that employs the low voltage supply of Figure 12. Through the interlock plug and switch S_1, the power line voltage is applied to the primary of filament transformer T_1, and to a series of tube heaters shown to the lower right of the transformer. Since the heater of the 6AL5 tube requires less current than those of the 12 and 25 volt tubes, the excess current passes through resistor R_2 to shunt or bypass the 6AL5. The secondary of T_1 applies 6.3 volts to the parallel heaters of the remaining tubes in the receiver.

The line voltage is applied through the fuse F_1 and resistor R_1 to the halfwave voltage doubler circuit. When the upper side of the line is negative, the C_1-D_1 circuit conducts to charge C_1 as indicated. The voltage across C_1 and the line voltage in series produce current in the D_2-C_2 circuit, when the upper side of the line is positive, to charge C_2 to twice the line voltage.

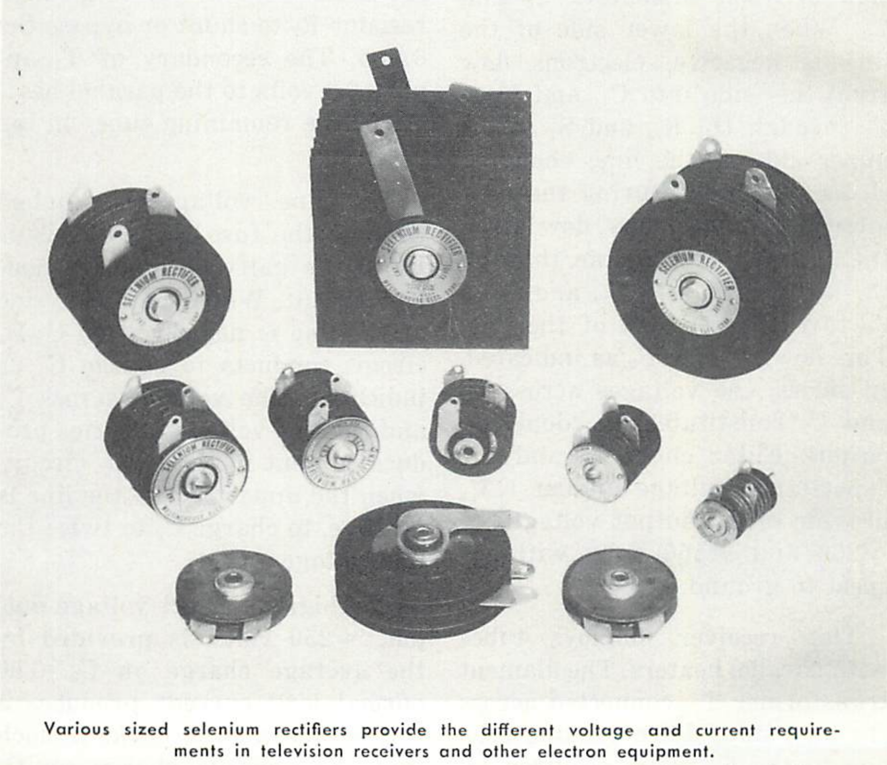
The highest direct voltage output, +250 volts, is provided by the average charge on C_2. The normal load current produces a voltage across filter choke L_1 such that the average charge on C_3

provides an output voltage of +240 volts. Likewise, load current produces a voltage across R_3 such that the voltage across C_4 is equal to +130 volts.

VOLTAGE DISTRIBUTION SYSTEMS

As explained, the low voltage supplies provide output direct voltages at different levels to accommodate the plate and screen grid operating requirements of the various tubes in the television receiver. The cathodes may connect directly or through bias resistors to ground, while the plates and screens connect through load and dropping resistors to one of the B+ terminals of the supply circuit.

Like the parallel-series arrangement of the heaters shown in Figure 7, the total current required from the low voltage supply may be reduced by connecting the plate circuits of the tubes in parallel-series also. This system is used often in television receivers employing selenium rectifier doublers in the low voltage supply, and is illustrated in Figure 13. In this



Various sized selenium rectifiers provide the different voltage and current requirements in television receivers and other electron equipment.

Courtesy Westinghouse Electric Corp.

typical case, some tube plate circuits operate at 250 volts and others at 125 volts. For simplicity, all other circuit components have been omitted, and the diagram of Figure 13 shows only direct plate and cathode connections.

Beginning at the right side of the diagram, the plate circuits of tubes V_7, V_{9A}, V_{10B}, V_{11B}, and V_{13} are connected across the entire voltage supply output from B + + to B −. Both plates of tube V_8 are connected to the boost voltage supply. Tubes V_3 and V_2 are connected in series across the entire supply so that part of the 250 volt output is across the V_3 plate circuit and the remainder across the V_2 plate circuit. Tube V_5 requires more than 250 volts, therefore, its plate is connected to the input of the voltage supply filter, at the junction between R_2 and C_2.

At the center is a group of seven tubes. The plate circuits of V_1, V_4, V_6, V_{9B} and V_{11A} are connected in parallel across B + + 250 v and B + 125 v, while the plate circuits of V_{10A} and V_{12} are connected in parallel across B + 125 and B −. The tubes have been grouped so that the total plate currents of V_1, V_4, V_6, V_{9B}, and V_{11A} are equal to the total plate currents of V_{10A} and V_{12}. The other circuit components, such as plate loads, are chosen so that the voltage across the plate circuits of V_{10A} and V_{12} is equal to exactly one half of the total supply voltage. With this arrangement there is 125 volts across B + + and B + and 125 volts across B + and B −.

Actually, the parallel-series plate connections are part of the signal circuits of the receiver, but due to their voltage divider operation they can be considered as a part of the voltage supply. Keep this general plan in mind, or it may be confusing to find the cathode of one amplifier tube connected to the plate of another.

Although not shown in Figure 13, for this voltage supply the tube heaters are connected across the 117 v a-c power line in a parallel-series arrangement to provide the proper voltage and current for each one.

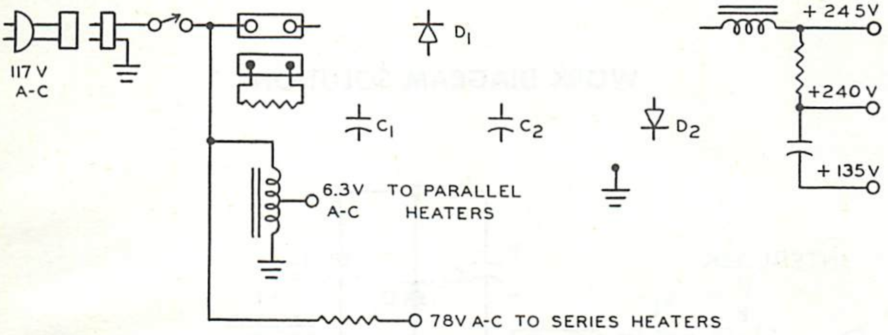
LOW VOLTAGE SUPPLY TROUBLES

The troubles that occur most frequently in low voltage supplies are defective rectifiers and leaky or shorted filter capacitors. Less frequent are opens or shorts in transformer windings or filter chokes, and opens in filter resistors. Usually, low voltage supply troubles affect both picture and sound quality. Therefore, these symptoms, existing together, indicate the fault to lie in the low voltage circuits. In cases of a voltage distribution system like that of Figure 13, a defect in any of the plate (or screen) circuits may affect the B+ and B++ voltages since, as mentioned, these circuits form the voltage supply divider system.

Up to this point, we have described the purpose of each section of the television receiver, and explained in detail the operation of each stage in the various sections. However, in the case of one of these sections, the r-f tuner, there are some important differences in design with regard to the frequency range in which the tuner operates. That is, although a tuner designed for reception in the uhf band performs the same basic functions as the vhf tuners described previously, the shorter wavelengths of the uhf carriers require somewhat different methods of accomplishing these functions, as well as modifications of circuit component design to provide adequate efficiency. Therefore, the construction and operation of the uhf tuners are described in the next lesson to complete the detailed explanations of the "internal" circuits of the television receiver.

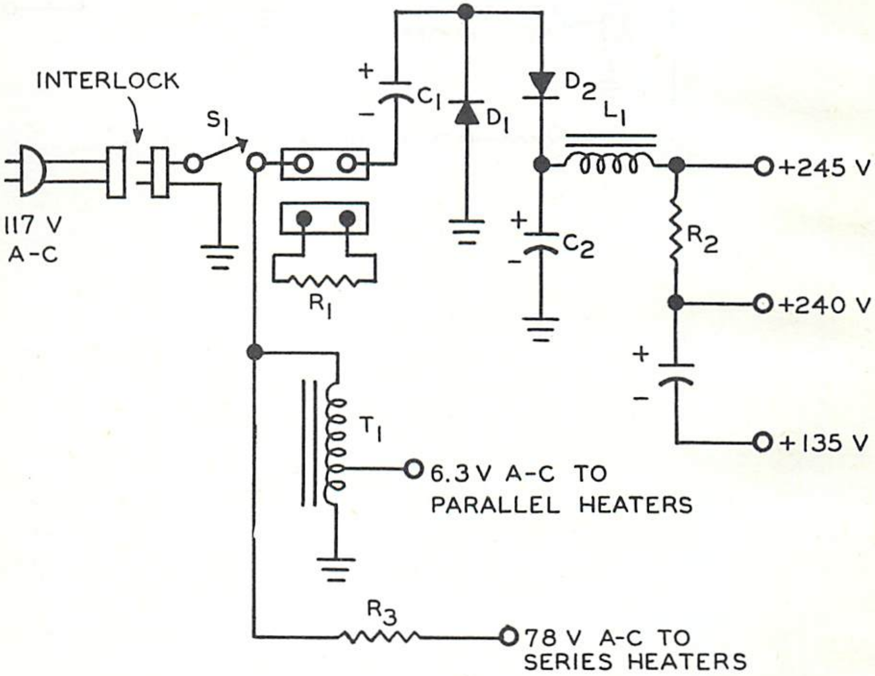
WORK DIAGRAM

Draw lines to complete the partial circuit of a half wave doubler arrangement. Indicate capacitor voltage polarity with plus and minus signs.



When you have finished, check your work with the solution on the back of the foldout sheet.

WORK DIAGRAM SOLUTION



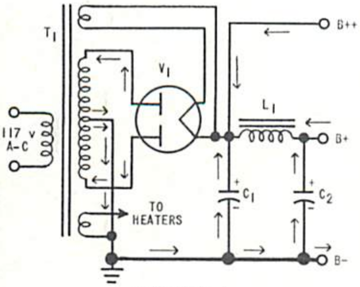


FIGURE 1

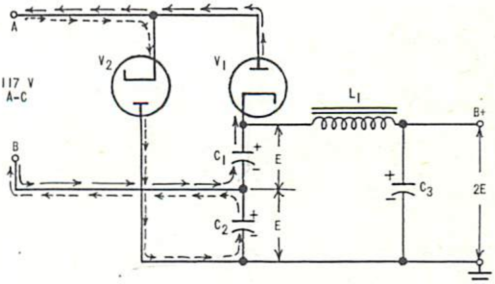
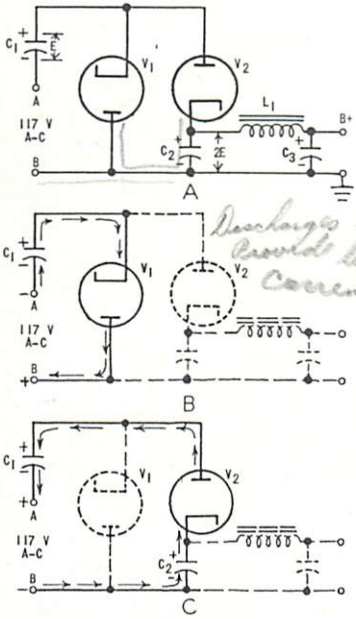


FIGURE 2



Discharges to provide load current

FIGURE 3

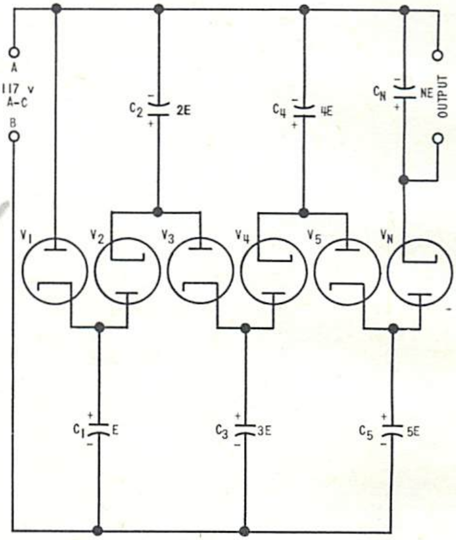


FIGURE 4

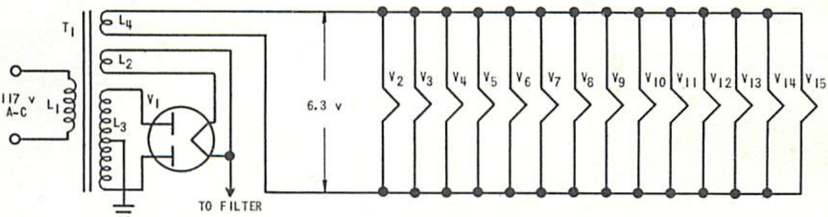


FIGURE 5

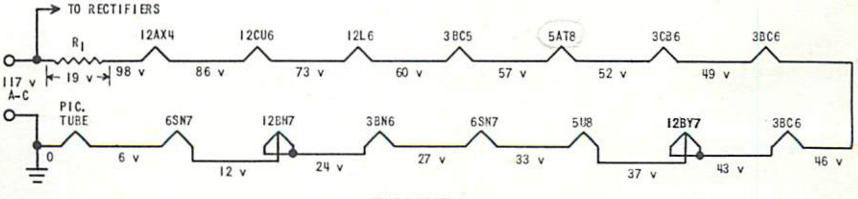


FIGURE 6

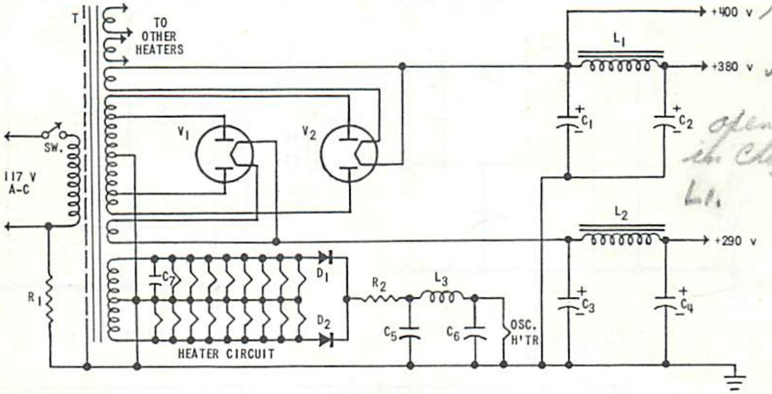


FIGURE 7

opening in choke L1.

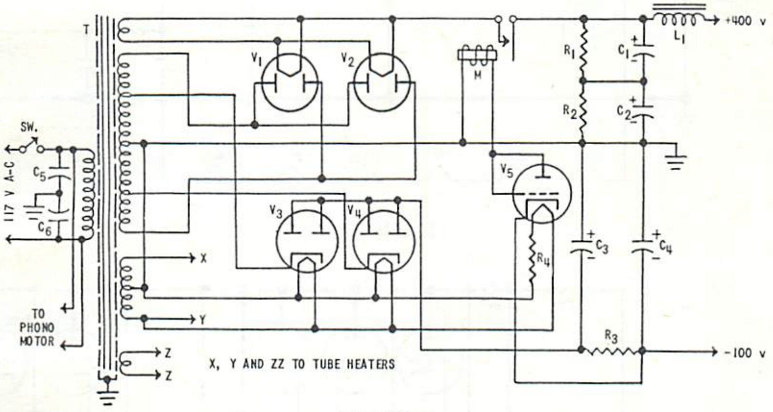


FIGURE 8

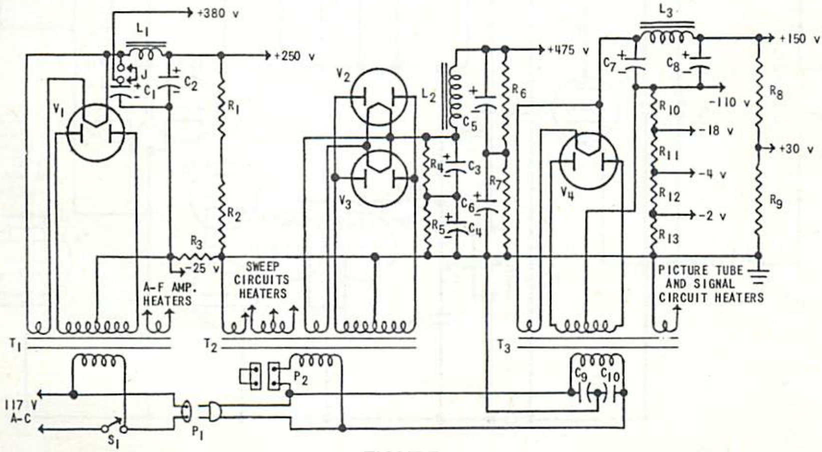


FIGURE 9

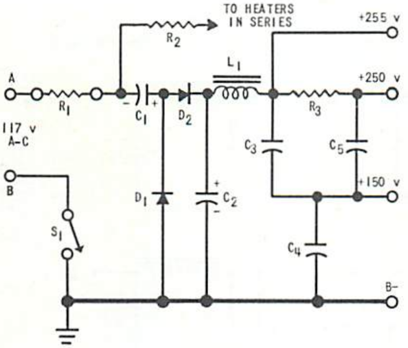


FIGURE 10

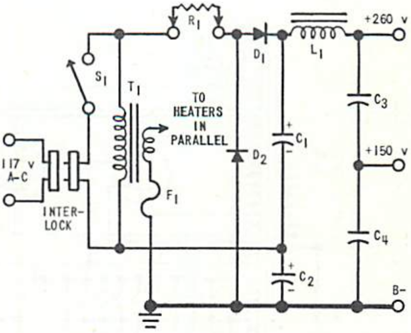


FIGURE 11

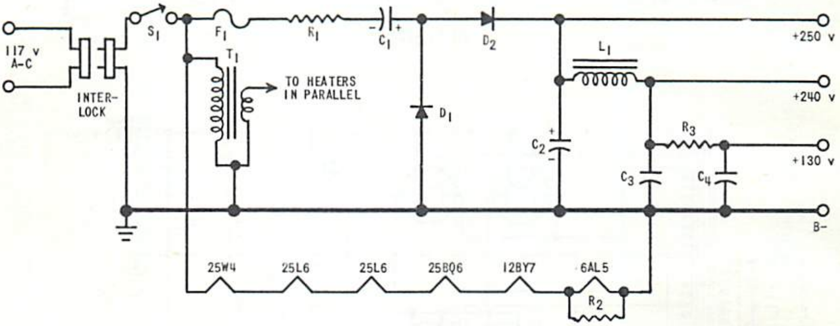


FIGURE 12

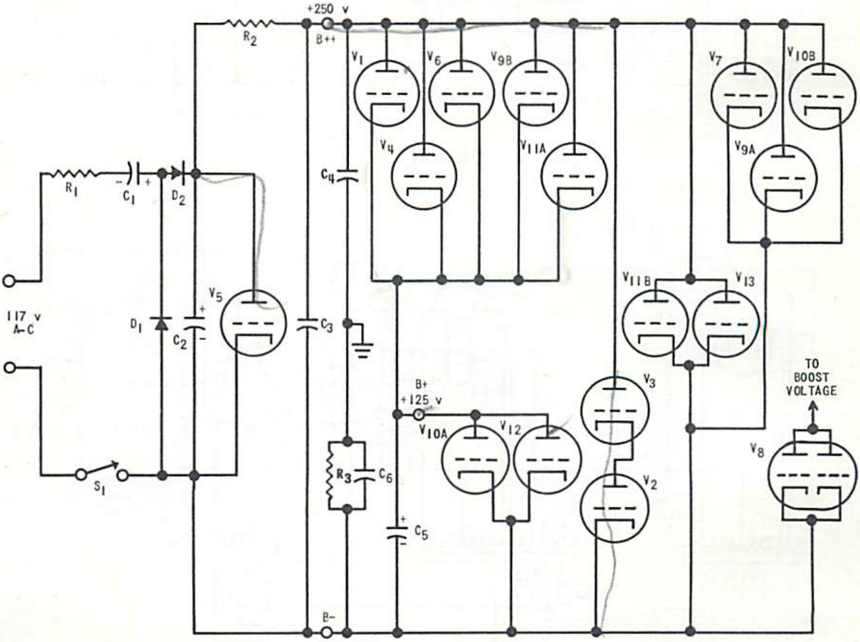


FIGURE 13

FROM OUR *Director's* NOTEBOOK

PERSEVERANCE CONQUERS ALL

Genius, that power which dazzles mortal eyes,
Is oft but perseverance in disguise;
Continuous effort, of itself, implies
In spite of countless falls the power to rise.
'Twixt failure and success the point's so fine,
Men sometimes know not when they touch the line.

Just when the pearl was waiting one more plunge,
How many a struggler has thrown up the sponge!
As the tide goes out, it comes clear in;
In business 'tis at turns the wisest win.
And oh! how true when shades of doubt dismay,
" 'Tis often darkest just before the day."

A little more persistance, courage, vim!
Success will down o'er fortune's cloudy rim.
Then take this honey from the bitterest cup;
"There is no failure save in giving up,
No real fall as long as one still tries,
For seeming setbacks make the strong men wise.
There's no defeat, in truth, save from within;
Unless you're beaten there, you're bound to win."

Yours for success,

W. C. DeVry

DIRECTOR

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